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THE

ANTIQUITY AND ORIGIN

OF THE

TRENTON GRAVELS.

BY

PROF. HENRY CARVILL LEWIS,

OF THE SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA.

EXTRACT

FROM PRIMITIVE INDUSTRY, OR ILLUSTRATIONS OF THE HANDIWORK OF THE NATIVE RACES OF THE NORTHERN ATLANTIC SEABOARD OF AMERICA.

BY CHAS. C. ABBOTT, M.D.

SALEM, MASS.:
GEORGE A. BATES,
1881.

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THE AGE OF THE TRENTON GRAVEL.

THE discovery of palæolithic implements in a gravel at Trenton, and the important relation which this holds toward the question of the antiquity of man in eastern America, make a careful determination of its age a matter of much interest.

While in the present state of our knowledge, we can fix no exact date for this gravel, it is possible nevertheless to ascertain approximately the relative geological time in which it was deposited. To solve this problem we must determine in the first place what relation this gravel holds toward all the other surface deposits of the Delaware valley, and in the second place what connection each or any of these deposits has with the great glacier which once covered a large portion of northern America. The writer, having been for several years engaged in a special study of the more recent geological deposits of southeastern Pennsylvania, has divided them into a series of distinct formations; of which the oldest is a clay of wealden or sub-cretaceous age, and the newest, a modern mud which is now forming on the banks of the Delaware and other streams. Of the five clays and four gravels which he has distinguished for convenience of study, but of which several may hereafter prove to be of closely related age, it will be necessary here to refer only to those which bear directly upon the subject under consideration.

THE YELLOW GRAVEL.

Nearly the whole of southern New Jersey and a small adjoining portion of Pennsylvania are covered by a deposit of yellow gravel

which has been variously known as quaternary, southern drift, etc. It extends southward all along the Atlantic coast in the region of tide water, rising some two hundred feet above the level of the ocean. As it caps the watershed between the Atlantic and the Delaware (elevation 190 feet), the writer has, in a former paper,[1] named it, for convenience, after a town in this watershed, where, in a railroad cut, it is well exposed,—calling it the "Glassboro gravel;" but in the present discussion, it will be sufficient to call it the YELLOW GRAVEL.

It is characterized by small waterworn pebbles, somewhat eggshaped in form, seldom above an inch in length, usually less, and composed of quartz or quartzite rocks. There are also occasional pebbles of flint, and of fossiliferous hornstone and chert. It contains no large boulders and has no pebbles of soft or readily decomposable rocks, and its pebbles have nearly all a weatherworn eaten appearance. Still other circumstances, such as the great amount of erosion it has suffered, and the decomposed state of the beds upon which it lies, point to the conclusion that it is an ancient deposit of aqueous origin, made during a submergence in preglacial times. Professor Cook, of New Jersey, states[2] that the glacial drift overlies and is more recent than the yellow gravel. This gravel, of newer tertiary age, is bounded on the northeast by a line of rocky hills which extends all along the southern Atlantic coast parallel to the ocean, and which we have called the UPLAND TERRACE.[3] This Upland terrace crosses the Delaware a few miles above Trenton, trending towards Princeton, and the yellow gravel is not found above this point.

THE PHILADELPHIA RED GRAVEL.

A more recent gravel, the PHILADELPHIA RED GRAVEL, is confined to the immediate valley of the Delaware. This gravel is a mixture of the

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[1] The Trenton gravel and its relation to the Antiquity of Man. Proc. Ac. Nat. Sciences, Phila. 1880, p. 296.

[2] Report on Clays, p. 17.

[3] The Surface Geology of Philadelphia and vicinity. Proc. Acad. Nat. Sciences, Phila., 1880, p. 258.

yellow gravel with more recent pebbles brought down the river valley. It contains numerous pebbles and boulders of soft triassic shale and of other rocks of the upper Delaware, it holds waterworn boulders of sometimes two feet or more in length, and it is distinctly stratified in horizontal or undulating layers. This red gravel, colored by peroxide of iron, is more clayey than the yellow gravel and lies at a lower level within a channel cut through the other gravel. The writer has recognized the representatives of both of these gravels in the same relative positions, on the Potomac near Washington.

The red gravel has been apparently deposited by an ancient flood of the river of great volume, at a time when it rose one hundred or more feet higher than at present. The presence of flow and plunge motion and of alternate sandy layers indicates a rapidly flowing current. While its stratified character, its smooth waterworn pebbles, and the soft decomposed rock upon which it rests, all show that it was not transported by ice, yet the presence of boulders which can be traced to the northern valley of the river, the absence of all traces of former life in the gravel, and the altitude above the present river which it attains, point to the melting of a great glacier as the origin of the flood which formed it. It is more than probable that this gravel belongs to the CHAMPLAIN EPOCH, the epoch of the melting of the great glacier whose southern terminus in the Delaware valley was near Belvidere, sixty-five miles above Trenton.

THE PHILADELPHIA BRICK CLAY.

Resting unconformably upon the Philadelphia red gravel is the next deposit in order of time—the PHILADELPHIA BRICK CLAY. This clay, of a yellow color, and of varying depth and purity, is here confined to the valley of the Delaware and its tributaries, and is characterized by the presence of numerous boulders which become more frequent as the river is ascended. The writer has traced the boundaries of this boulder bearing clay up to the glaciated region and finds that it uniformly rises to a fixed limit of one hundred and fifty to one hundred and

eighty feet above the river. Where the valley is wide, as at Philadelphia and Trenton, the clay is pure and fit for brick-making, but in narrow or steep portions of the valley the current has been too swift for the deposition of clay and it is represented by occasional, stranded, waterworn boulders. This clay rests against the upland terrace from Trenton to Philadelphia, at an elevation of one hundred and fifty feet. On the Lehigh river, a tributary of the upper Delaware, where[4] the bed of the river is more than two hundred feet higher than at Philadelphia, the clay rises one hundred and eighty feet above the river.

Whenever both clay and gravel are present, the clay lies unconformably upon the latter. Generally it lies in a series of crests and hollows upon the gravel, the clay occupying the hollows between the crests of gravel. The following section, observed in Philadelphia, shows six well marked waves of gravel and clay.

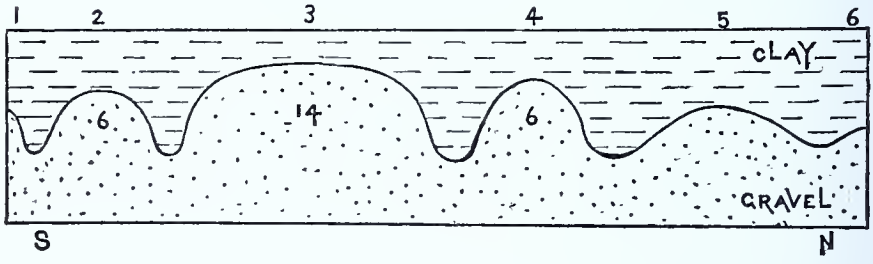

FIG. 1.

Frequently there occur, in or upon this clay, boulders of large size. Thus in Philadelphia there are smooth boulders of Silurian rocks between four and five feet long, at an altitude of one hundred feet above the river; and on the Lehigh above the Gap, we have found a boulder six feet long, elevated one hundred and fifty feet above the river at that place. In the vicinity of Bethlehem, thirty miles below the terminal moraine, the boulders in the clay sometimes show glacial striæ. It hardly admits of doubt that these boulders were borne by large cakes of floating ice derived from the base of the melting glacier.

[4] We designate as "upper Delaware," the steep narrow portion of the river above tide water and as "lower Delaware," the tidal portion of the river, or from Trenton, southward to Delaware bay.

That this was an epoch of submergence is indicated by the elevation of the deposit. While the underlying gravel was deposited by a rushing flood, it was not until quieter conditions had prevailed that clay could be formed. It is probable that this clay may be assigned to a period when the land stood one hundred and fifty feet or more below its present level, and when the cold waters from the melting glacier bore ice rafts which dropped their boulders. No shells or other signs of life have as yet been found in the brick clay, and it is inferred both that the water was fresh and that it had a temperature too low to support life.

In the consideration of the age of this clay, the amount of erosion it has suffered is an important feature. Unlike the modern alluvial clays of dark color, it does not appear on the immediate banks of streams, and has disappeared, wherever eroding agencies have been most active.

Finally, it is of interest to find that the clay which cements the unstratified "TILL," the "ground moraine" which covers the glaciated region to the north, is of a character so similar to the Philadelphia brick clay, that there is a strong probability that the latter was derived, in great part, directly from the grinding base of the glacier. The Philadelphia brickclay becomes more and more stony as we proceed northward, until in valleys at the base of the terminal moraine of the glacier its stones are almost as numerous as those of the true glacial till. Deposits of this boulder-bearing brickclay have more than once been confounded with glacial moraines. The latter, however, as is well known, may be distinguished by the abundance of angular and ice-scratched boulders and by the absence of stratification.

The relation of the Philadelphia brickclay to the till will be further discussed after the moraine and the other products of ice action have been described.

THE TRENTON GRAVEL.

The last and newest of all the gravels—a formation which when first studied at Philadelphia seemed of slight importance, and was called by

the writer the "river gravel and sand," but which from its great development at Trenton is now appropriately known as the "TRENTON GRAVEL"—forms the subject of the present paper. At Philadelphia it lies close along the river, within all the older gravels, and rises but a few feet above the water. It is in this alluvial gravel, the latest, except the recent mud flats, of all the surface formations, and in this gravel only, that traces of man have been found.

The Trenton gravel at Philadelphia is composed principally of a sharp, micaceous sand, which below water-level is a quicksand, overlying a clean, dark gray gravel, whose pebbles are made exclusively of the rocks forming the upper valley of the river. The pebbles of this gravel, unlike those of the older gravels, are generally flat—a shape characteristic of true river gravels. Quartz pebbles are much less numerous than in the other gravels. Irregular strata of "bar-sand" frequently alternate with the gravel. The islands in the river and its banks are made of this gravel, and from data obtained from artesian wells, it appears that in the middle of the river it is about one hundred feet deep, lying upon rock. It therefore fills up an ancient channel of the once larger river, and the river now flows upon it. Occasional large boulders lie upon the sand.

It is to be especially noted that the Trenton gravel is bounded by a continuous hill of older red or yellow gravel, and that it therefore lies in a channel previously excavated through those gravels, down to the underlying rock. On tracing the Trenton gravel up the river, it is found gradually to extend farther from its banks and to rise to a greater elevation above it, until in the vicinity of Trenton, thirty miles above Philadelphia and at the head of tide-water, this formation extends several miles back from the river and rises between thirty and forty feet above it.

A few miles above Trenton the valley of the river narrows, and from here up, the river flows upon a rocky bottom, and the Trenton gravel is shallow and confined to the immediate vicinity of the river. It forms a low terrace, seldom over ten feet high, and extends as a "flat" on either side of the river. It continues up into glaciated regions, where it

appears to form the lowest and most recent terrace. The writer has observed similar gravels on the Susquehanna and Allegheny rivers, and it is probable that they occur on all rivers rising in the glaciated region.

THE GEOLOGY OF TRENTON.

The great development of this formation at the city of Trenton, and the archæological interest attached to it at this place, call for a yet more detailed description.

Trenton lies at the junction of three great formations, the Azoic or Gneissic, the Triassic, and the Cretaceous. A narrow belt of steeply-inclined gneissic rocks, which in Pennsylvania are extensively developed, passes through the centre of the city, and is laid bare in several places. Resting unconformably upon the northern edge of the gneiss is a series of red sandstones and shales which have a gentle dip to the north. These belong to the Triassic formation, which extends for forty miles up the Delaware, and which is intersected by frequent trap dykes. Immediately south of Trenton is a plastic clay of lower cretaceous or Wealden age, which rests upon the southern edge of the gneiss, and dips very gently toward the sea. The more recent deposits of sand and gravel lie in horizontal strata upon these three formations, and often cover them so completely as to hide them from sight.[5]

The Trenton gravel, which is here coarser than at Philadelphia, extends in the shape of a horse-shoe eastward and southward of the city of Trenton. It forms a bay, which extends fully four miles back from the river, and which has one extremity in Trenton, at "Five Points," and the other at a distance of two miles below the city. It is a level plain, which is bounded throughout by a hill, on which appear the older yellow or red gravels and the brickclays. Since it was depos-

[5] For full descriptions of these formations, see Geology of New Jersey. 8vo. Newark, N. J. 1868. Geo. H. Cook, State Geologist.

ited, the river has cut down through it to the gneiss below, forming a bluff. South of the city the river is bordered by marshy meadows formed of recent alluvial mud, beyond which rises the bluff.

The writer has prepared a map (page 11) showing the extent of the Trenton gravel in this vicinity. That portion of the map which is unruled represents territory covered by red or yellow gravel and the brickclays. The upland terrace bounding these older deposits is outside of the limits of the map. The recent alluvial mud is shown bordering the river in places below the limit of tide-water, but is absent above that point. An interesting ancient island of red gravel is shown in Pennsylvania. It will be noticed that the Trenton gravel, confined to the immediate vicinity of the river above Trenton, suddenly spreads out like a bay at that city. Localities where palæolithic implements have been found below the surface are marked by a small cross.

The Trenton gravel, as exposed on the river bluff and in the numerous and long railroad cuts in the city, is seen to consist of a dark gray stratified gravel, overlaid by a gray sand. The gravel contains no clay, but has frequent sandy layers in which "flow and plunge" structure may be observed. Its pebbles are smooth, and generally of a flat oval shape. They are composed entirely of the rocks of the upper Delaware valley. This gravel has been well described by Professors Cook[6] and Shaler.[7] The sand overlying the gravel varies in depth from three to eight feet, and has all the characters of a true river sand. Waterworn boulders frequently lie in or upon this sand, and are rarely eight feet in length. It is difficult to account for the presence of such large boulders, except by assuming that they have been dropped from ice-rafts which floated down the once greatly enlarged river. They were dropped at a time immediately subsequent to that in which the gravel was deposited and when the violence of the flood had diminished. The depth of the

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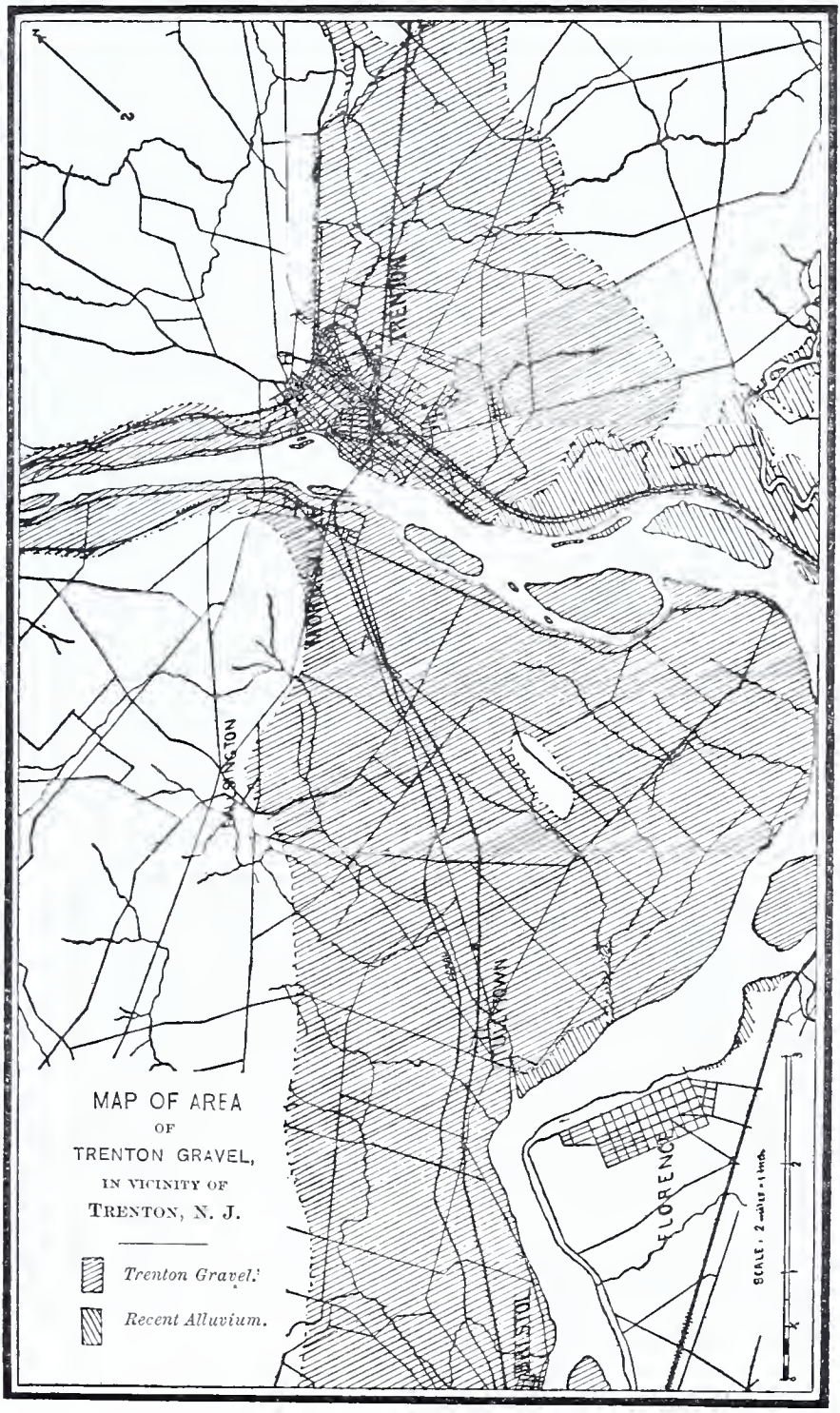
[6] Annual Report, 1877, p. 21.

[7] Annual Report of Peabody Museum, 1877, p. 44.


TRENTON
MORRISVILLE
EDDINGTON
LITTLE BROWN
BRISTOL
FLORENCE
MAP OF AREA
OF
TRENTON GRAVEL,
IN VICINITY OF
TRENTON, N. J.
Trenton Gravel.
Recent Alluvium.

Trenton gravel varies from perhaps forty feet in the centre of the "horse-shoe," near the river, to six or eight feet near its edges. Near the house of Dr. Abbott, not far from the extremity of the "horse-shoe," the Trenton gravel and sand is about fourteen feet thick and overlies the series of older strata which here compose the greater part of the bluff. The following section is seen about two miles south of Trenton.

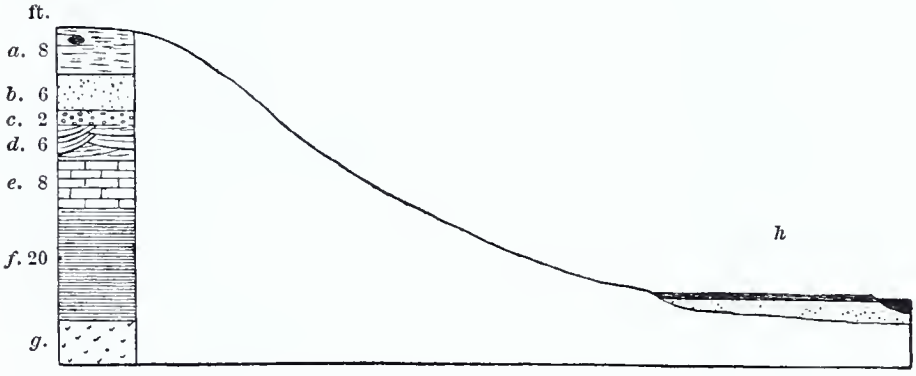


FIG. 2.— Section of bluff two miles south of Trenton, New Jersey. *a*, *b*, TRENTON GRAVEL; Implements — *a*, fine gray sand (boulder); *b*, coarse sandy gravel; c, red gravel; *d*, yellow gravel (preglacial); *e*, plastic clay (Wealden); *f*, fine yellow sand (Hastings?); *g*, gneiss; *h*, alluvial mud; *i*, Delaware river.

THE TRENTON GRAVEL A TRUE RIVER GRAVEL.

The presence of large boulders in the bluff at Trenton, and the extent and depth of the gravel at this place, have led to the supposition that there was here the extremity of a glacial moraine. Yet the absence of "till" and of scratched boulders, the absence of glacial striæ upon the rocks of the valley, and the stratified character of the gravel, all point to water action alone as the agent of deposition. The depth of the gravel and the presence of the bluff at this point, are explained by the peculiar position that Trenton occupies relatively to the river.

Trenton is in a position where naturally the largest amount of a river gravel would be deposited, and where its best exposures would be

exhibited. It is at the point where a long, narrow valley, with precipitous banks and continuous downward slope, opens out into a wide, alluvial plain at a lower level. It is here that the rocky floor of the river suddenly descends to ocean level, and even sinks below it, forming the limit of tide-water. Thus any drift material which the flooded river swept down its channel would here, upon meeting open ground, be in great part deposited. Boulders which had been rolled down the inclined floor of the upper valley would here stop in their course and all be heaped up with the coarser gravel in the more slowly flowing water, except such as cakes of floating ice could carry oceanward. On the other hand, the finer gravel and sand would be deposited farther down the river. Thus it is that the material, which at Philadelphia is generally fine, grows coarser as the river is ascended.

We have seen that the gravel which at Philadelphia forms the bed of the river and rises only slightly above it, at Trenton forms a cliff nearly fifty feet high. The river has cut through the gravel at Trenton, but still flows upon it at Philadelphia. The fact follows as a natural consequence of the position of Trenton. Having heaped up a mass of detritus in the old river channel as an obstruction at the mouth of the gorge, the river, so soon as its volume diminished, would immediately begin wearing away a new channel for itself down to ocean level. This would be readily accomplished through the loose material, and would be stopped only when rock was reached. On the other hand, that gravel which had been deposited at places farther down the river where its bottom was below ocean level, would remain uneroded, or nearly so. When the river had attained the level of the ocean there would be no occasion to cut a deep channel, and it would therefore flow on top of the gravel which it had deposited.

It is necessary that this point should be understood, since it has been thought that to account for the high bank at Trenton, an elevation of the land must have occurred. It will be seen that the

present explanation requires no change of level from that at present existing. An increase in the volume of the river will explain all the facts. The accompanying diagram will render this more clear.

The fact of the river having cut through the gravel at Trenton, while at Philadelphia it flows upon it, is due to the configuration of the rock floor of the river, which at Trenton rises above ocean level, and at Philadelphia lies nearly 100 feet below it.

A few miles north of Trenton, all the older oceanic gravels disappear and two formations alone remain. These are the Philadelphia boulder-bearing brickclay and the Trenton gravel. Both are confined to the valley, and until we reach the region once covered by the glacier, no drift of any kind occurs above the limit of the brick-clay.

The Trenton gravel, now confined to the sandy, flat borders of the river, corresponding probably to the "intervale" of New England rivers, lies within a channel cut through the brick clays. That it is much more recent than the brickclay is shown both by the fresh appearance of its pebbles, and by the less amount of erosion it has suffered. Unlike the land covered by older surface formations, that covered by the Trenton gravel is remarkably level and free from hillocks or ravines. The change in topography may be well seen in the neighbor-

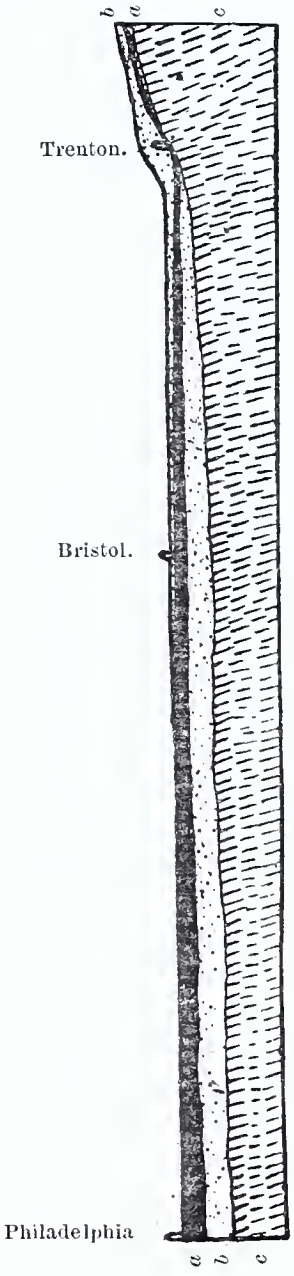


FIG. 3.—Longitudinal section of Valley of Delaware River, from Trenton to Philadelphia, showing position of the river gravel, with reference to the river. *a*, Delaware river; *b*, Trenton gravel; *c*, gneiss.

hood of Trenton, and can be noticed almost anywhere along the valley. This difference is much more marked when comparison is made with the oceanic gravels. The Trenton gravel exhibits a topography peculiar to a true river gravel. Frequently, instead of forming a flat plain, it forms higher ground close to the present river channel than it does near its ancient bank. Moreover, not only does the ground thus slope downward on retreating from the river, but the boulders become smaller and less abundant. Both of these facts are in accordance with the laws of river deposits. In a time of flood the rapidly flowing water in the main channel, bearing detritus, is checked by the more quiet waters at the side of the river, and is forced to deposit its gravel and boulders as a kind of bank.

The section across the Delaware river above Trenton shows this topography and the relation of the Trenton gravel to the brickclay.

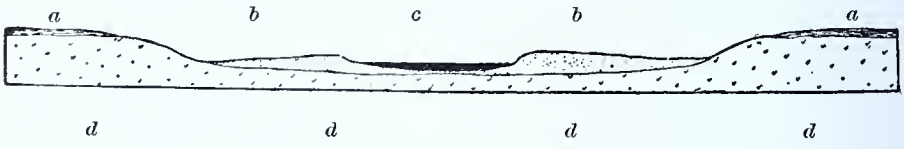


FIG. 4.—Section across the river at North Trenton. *a*, Philadelphia brickclay with boulders; *b*, Trenton gravel; *c*, Delaware river; *d*, gneiss.

Having now shown that the Trenton gravel is a true river gravel of comparatively recent age, it remains to point out the relation it bears to the glacial epoch.

THE TERMINAL MORAINE.

At or near the southern limit of the great ice-sheet is an accumulation of drift hills of characteristic rounded shape, forming a true terminal moraine. These hills, generally covered by large transported boulders, are connected together laterally, in an irregular manner to form a ridge at right angles to the ice motion. They are composed entirely of drift and form a remarkable accumulation which, rising sometimes over two hundred feet in height, can be traced continuously across the country.

Across northern New Jersey, Prof. Cook[8] has carefully traced it from Staten Island, on the east, to Belvidere, on the west; and has shown that it winds over hills and across valleys in such a manner, that by no other known agency than a great glacier, could it have been produced. Mr. Warren Upham[9] has traced it from Staten Island, eastward, through Long Island to Block Island and Cape Cod. Its course throughout Pennsylvania will shortly be made known. Similar moraine accumulations have been followed through a number of the western states by Profs. Whittlesey, Winchell, Chamberlin, and others. In Wisconsin, Prof. Chamberlin,[10] and in Minnesota, Mr. Upham,[11] have made investigations which indicate that these accumulations mark the halting places of the glacier during the period of its grand retreat.

This great moraine, which can be traced across the continent, marks the termination of the ice-sheet throughout the principal portion of the last glacial epoch. There is some evidence that in an earlier period a glacier advanced south of that limit. The moraine, throughout its whole course, is composed in great part of an unstratified deposit of angular and rounded boulders and pebbles embedded at all angles in a stiff clay, and very frequently scratched and polished. Occasional stratified sandy beds also occur. Curious features of glaciated regions which may be seen from Maine to Minnesota are the "kettleholes" or bowl-shaped depressions with no outlet, each of which perhaps marks the place where a mass of ice was buried in the sand, afterwards to melt and form a hollow. North of the moraine, the glacier has left undoubted traces in the universal covering of unstratified boulder clay or *till*, in the smoothed and grooved rocks, the transported boulders, the frequency of lakes and swamps caused by unequal distribution of the drift, the long gravel ridges known as *kames*, and the terraces along the rivers. These phenomena are wanting south of glacial action.

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[8] Annual Reports of Geological Survey of New Jersey, 1877 and 1878.

[9] Proc. Amer. Assoc. Adv. Sci., vol. xxviii, 1879.

[10] Geology of Wisconsin, ii, p. 205, et seq., 1877.

[11] Geological Report of Minnesota, p. 73, 1879.

The materials forming the moraine in eastern Pennsylvania are in great part derived, not from far distant localities, but from the immediate vicinity to the north. The same may be said of the till and especially of its lower portions. There is no evidence of iceberg action in either of these deposits. As already stated, the Philadelphia brickclay, on the other hand, holds boulders generally brought from longer distances.

The moraine on the Delaware, sixty miles above Trenton, is distinctly marked on both sides of the river. In the valley, its materials have been modified by water action and spread out near Belvidere as a plain of stratified gravel. The pebbles on the higher ground show glacial scratches, while those in the valley have been subsequently waterworn. In Pennsylvania the moraine trends from Belvidere in a northwest direction, crossing the Kittatinny Mountain, east of the Wind Gap, and being well shown in each valley that it crosses.

During the melting of the glacier, either the ice or the morainic material so blocked up the Water Gap, as to form temporary lakes north of that point, by damming back the water. Thus we find, in the vicinity of Stroudsburg, Pennsylvania, a series of beautiful, level-topped terraces, the highest rising seventy-five feet above Brodhead's creek. Here, too, is what appears to be a "kame,"—a long, steep ridge of stratified gravel formed probably by sub-glacial streams, and afterwards partially covered by the terrace material. These curious features of glaciated regions have been well described by Rev. Geo. F. Wright[12] in Massachusetts, by Mr. Warren Upham[13] in New Hampshire and Vermont, and by Prof. G. H. Stone[14] in Maine, and it is shown that while more recent than the "till," they are older than the stratified valley drift.

The whole drainage area of the Delaware, north of the Water Gap, shows undoubted evidences of glaciation. There are many facts

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[12] Proc. Boston Soc. Nat. Hist., vol. xix, p. 47; vol. xx, p. 210.

[13] Amer. Journ. Science, Dec. 1877, p. 460; New Hampshire Geological Survey, vol. iii.

[14] Proc. Amer. Assoc. Adv. Science, vol. xxix, 1880.

which indicate that the ice even close to its lower terminus had a thickness of over one thousand feet, which increased northward. Penobscot Knob, 2,100 above the sea and only about twelve miles north of the limit of the glacier shows transported boulders and glacial scratches on its very summit; while in the Wyoming valley, immediately north, the presence of a glacier is shown by terraces and kames.

THE AGE OF THE PHILADELPHIA BRICK CLAY.

In discussing the origin of the Trenton gravel, it will be most important that the age of the Philadelphia brickclay—a formation directly connected with the melting of the glacier—should be considered. We have already seen that while both the brickclay and the Trenton gravel are confined to the same valley, the former is of much greater extent than the latter, and was deposited at an earlier age. North of the moraine it is not uncommon to find stratified sands alternately with beds of clay, but in no case has the Trenton gravel been observed either to contain beds of clay or to alternate with them, and the conclusion already arrived at, that the Trenton gravel lies within a channel which had been excavated through the brickclay, is confirmed by all the facts observed. If, therefore, it can be shown that the Philadelphia brickclay is of Champlain age, and subsequent to the formation of the "till," it will necessarily follow that the Trenton gravel belongs to the extreme end of glacial times, or is post-glacial.

At Bethlehem, Pennsylvania, some fifteen miles below the moraine, a most instructive section is exposed. Here, upon the summit of a hill rising one hundred and eighty feet above the Lehigh river, the brickclay, holding large smooth boulders, lies unconformably upon a deep deposit of a stratified gravel, intermediate in its characters between the "modified drift" of glaciated regions and the Philadelphia red gravel. The gravel, of which thirty feet in depth is exposed, is distinctly stratified, and is composed of waterworn pebbles with occasional coarse sandy layers, and with no boulders. Identical

sections may be observed in the kames and terraces north of the Delaware Water Gap. It is a well established fact that these formations overlie and are more recent than the unmodified till, which was deposited both as the terminal moraine, or beneath the ice-sheet as a ground moraine, and that they represent later stages in the melting of the glacier. The Philadelphia brickclay, now shown to be still more recent, belongs, therefore, to a late portion of the Champlain period. It appears to have been formed at a period of submergence during the retreat of the glacier.

A study of the valley of the Lehigh river throws much light upon the age of the brickclay. In the narrow valley extending from glaciated regions down to the Lehigh Water Gap, the clay is represented by waterworn boulders, often of large size, stranded on the banks. These are most numerous near the river, and are very scarce at their extreme outer limit, one hundred and eighty feet above the water. From the Lehigh Gap to the Delaware the valley is broad and the clay finely developed. Its boulders are so very much more numerous than they are at Philadelphia, that a section through it nearly resembles a section through a moraine, and the two phenomena have been confounded. The action of an ice-bearing flood of immense magnitude is clearly shown all along the river. Some of the clays which border the great lakes, rising one hundred to two hundred feet above them, are perhaps of similar age. In a paper on the age of the Trenton gravels, Rev. G. F. Wright,[15] who has examined a number of localities with the writer, estimates the glaciated region drained by the upper Delaware to be about six thousand square miles, and shows that even supposing the ice to have been fifteen hundred feet deep over this area, it would be impossible to provide for a flood of sufficient magnitude to account for the whole deposit of Philadelphia brickclay, without assuming an extensive depression of the valley. Professor Dana, in an exhaustive study of the floods produced in southern New England during the melting of the glacier, shows that the

[15] Proc. Bost. Soc. Nat. Hist., Jan. 19, 1881.

Connecticut river rose one hundred and fifty to one hundred and eighty feet above its present level. Many authorities might be cited to show the universality of this flood.[16]

Whether the stratified drift which forms the New Haven plain[17] belongs to the epoch of this same great flood, or whether, with the Trenton gravel, it was formed in more recent times, is a question, the discussion of which brings us back to the problem presented at the beginning of this chapter, namely, the geological position of the Trenton gravel.

THE AGE OF THE TRENTON GRAVEL.

From the facts already cited, it will be seen that two hypotheses only can apply to the Trenton gravel. It is either *post*-glacial (A) or it belongs to the very last portion of the glacial period (B).

The view held by the late Thos. Belt[18] can no longer be maintained. In his numerous papers in the Quarterly Journal of the Geological Society of London, and in the Quarterly Journal of Science, he endeavored to prove the pre-glacial age of the implement-bearing beds of England and elsewhere. In a paper "On the Discovery of Stone Implements in Glacial Drift in North America," he fails to recognize any distinction between the gravels, and holds that the Trenton gravel is older than the brickclay or "pre-diluvial,"—*i. e.*, pre-champlain. As we have seen, the Trenton gravel is truly post-glacial. It only remains to define more strictly the meaning of that term. There is evidence to support each of these hypotheses now set forth, and it may be that, in considering them in order, both may be found to be true.

(A) That the Trenton gravel is a *post-glacial* river deposit, made at a time when the river was larger than at present, is a conclusion warranted by many facts. We have seen that it represents the very

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[16] On Southern New England during the melting of the Glacier. Amer. Jour. Science, vol. x, Sept. to Dec., 1875.

[17] Dana, *loc. cit.*, p. 414.

[18] Quarterly Journal of Science, London, January, 1878, p. 55.

last of the gravel deposits of the upper Delaware valley. It cannot be assigned to the glacial period, except by assuming that there have been no river gravels deposited since that time — an assumption difficult to maintain. River gravels which are truly post-glacial occur in glaciated regions along the bottom of valleys. These lie only a few yards above the water, and are bordered by terraces of stratified drift. They form a sandy plain, on top of which boulders frequently lie.

Where terraces occur, they form the lowest of these and appear to have been made up from the materials of the older deposits. This same sand and gravel can be traced down the Delaware, past the terminal moraine, into the non-glaciated regions. At Belvidere, we can observe, 1st, the unstratified moraine, some distance back from the river; 2nd, the stratified drift formed from the moraine and spread out as a plain at a lower level, and which is of the same age as the terraces above the Water Gap; 3rd, a sandy river gravel newer than either of these, which forms the low, sandy plain along the river and is of limited extent. Farther south, we find this last gravel all along the stream. It becomes deeper as we go down the valley. Frequently it may be observed to form a bank close to the stream and to slope gently downwards towards the side of the valley — a feature already described as belonging to this gravel.

Finally, on reaching Trenton, we find this same gravel, with the same characteristics, but of greater depth and extent, spread out to form the plain upon which part of that city stands. There has been no break in the sequence of facts observed, and the conclusion is forced upon us that the deposit at Trenton is the same as that which borders the upper parts of the river, and that both are post-glacial. If the Trenton gravel were the same as the upper terraces of the glaciated regions, there should be some traces of such terraces between the moraine and Trenton. Yet none such have been observed, and the only continuous terrace is the lowest one, which finally merges into the Trenton plain.

The Trenton gravel differs in several respects from the stratified drift of the New Haven plain — a deposit typical of New England

rivers. During a recent examination of that locality, under the guidance of Prof. Dana, it was observed that it resembled the gravel of the terraces more than that of the Trenton plain. Unlike a true river gravel, the boulders did not lie on top of the deposit, but below it, as though the glacier, in its retreat, had first dropped the boulders and then covered them with sand and gravel carried along by the flood issuing from its base. The New Haven plain, unlike that of Trenton, is characterized by numerous kettle-holes,—the result probably of ice action,—and all of its features suggest that it was formed while the melting glacier was close at hand. The Trenton gravel, on the other hand, shows no evidences of ice action. That the boulders upon its surface were dropped from ice-cakes is however probable. The materials of the gravel are composed of a mixture of pebbles brought from the stratified moraine drift of Belvidere and northward with pebbles formed in the river bed farther south, both of which the flood has brought down and restratified.

A flood of sufficient extent to produce the deposit at Trenton need not necessarily be of very great magnitude. From the upper border of Pennsylvania to Trenton, the Delaware descends over nine hundred feet—an average fall of five feet per mile. Even from the Delaware Water Gap to Trenton the descent is about four feet to the mile. Since in a great part of its course the valley is a narrow one, it will be seen that a moderate increase of the volume of the river at its headwaters could produce all the effects observed at the point where the valley suddenly opens out. A similar post-glacial flood has been recognized in England and upon the continent. Mr. Tylor[19] call the age of the flood the "Pluvial period," remarking,[20] that "the existence of a glacial period almost necessitates that of a pluvial period, commencing prior to the glacial and continuing after it, occupying a region south of that occupied by the ice and snow."

Although the Trenton gravel was subsequent to the great melting

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[19] Quart. Journ. Geol. Soc., vol. xxii, p. 463; vol. xxiv, p. 103.

[20] *Loc. cit.*, vol. xxiv, p. 120.

which produced the brickclay, it is possible that it was immediately subsequent to the final disappearance of the last traces of the ice at the headwaters of the Delaware, and that it is post-glacial only in a local sense. It is more recent than the glacier at the time of its retreat from Belvidere, but there is no proof that the glacier did not linger considerably later in more northern regions.

(B) Thus the second hypothesis may be true, as well as the first. In considering the Trenton gravel as entirely post-glacial, there arises the difficulty of assigning a sufficient origin for the flood which formed it. No flood within the historical epoch has been known to at all approach in magnitude those which in time deposited the Trenton gravel. No boulders of the size found in and upon that gravel are now carried down the river by floating ice. At the time of the Trenton gravel floods, the lower part of the site of Philadelphia, the whole of that of Bristol and Tullytown, and nearly all of that of Trenton, were submerged. No rain-storms within the recollection of man, or mentioned in tradition, could have supplied such an amount of water, and no origin for such extraordinary rains is suggested, except under a very different climate or by evaporation from a melting glacier.

That the climate was then cold is further indicated not only by the suggestion that there was then probably very large masses of boulder-bearing ice floating in the enlarged river, but also from the fact that fossil remains of arctic animals, as the reindeer and walrus, have been found in post-glacial deposits in New Jersey and Pennsylvania, which indicate a continuance of a colder climate than now, after the disappearance of true glacial conditions. The frequent occurrence of boulders resting upon the sand overlying the gravel suggests the grounding of large ice-cakes derived from some mass of ice large enough to be called a glacier.

Since the present channel of the river at Trenton has been excavated after the deposition of the Trenton gravel at that place, and since such excavation would necessarily begin so soon as the river ceased to deposit any gravel, it follows that the river could have flowed on top of the deposit at Trenton only when, as a flood of great

volume and rapidity, it bore along large masses of gravel. Although possible, it is difficult to separate completely such a flood from the melting of a glacier. Yet, if a glacier, it must have been very different, both in age and extent, from that whose melting caused the Philadelphia brickclay. Judging from comparative erosion alone, one might be induced to think that perhaps as much time elapsed between the deposition of the brickclay and that of the Trenton gravel as has elapsed from the latter period to the present day.

From the limited extent of the Trenton gravel, it is inferred that if caused by a glacial flood, such glacier must have been either a local one or at least have had its southern extremity confined to the Delaware valley. The melting of a local glacier in the Catskill Mountains would probably result at the headwaters of the Delaware in a continued flood of sufficient volume, if supplemented by the action of floating ice, to form the Trenton gravel. Whether such a glacier was a lingering remnant of the great glacier which had retired from Pennsylvania and New Jersey, and still existed farther north, or whether there was a separate and more recent glacier belonging to a second glacial epoch, is as yet an open question.

There are not wanting evidences of a second glacial epoch in America. Intercalated beds, which, according to their geographical position contain land plants or marine shells, have frequently been found with true "till" both above and below them. These offer "undeniable evidence that animals and plants occupied the land during temperate interglacial epochs, preceded and followed by an arctic climate and ice-sheets like those now covering the interior of Greenland and the Antarctic continent."[21] Prof. Chamberlin, of Wisconsin, in a recent letter to the writer, suggests that the Philadelphia red gravel and brickclay were formed at the time of the first and most extended glaciation, and a channel excavated through it during the interval of deglaciation; while the second advance of the glacier formed the New Jersey moraine, and *its* final retreat, the Trenton gravel.

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[21] Geol. of Minnesota, Report for 1877, p. 37; Report for 1879, p. 115.

A second glacial period in Europe, known as the "Reindeer Period," has long been recognized. It appears to have followed that in which the clays were deposited and the terraces formed, and may therefore correspond with the period of the Trenton gravel. If there have been two glacial epochs in this country, the Trenton gravel cannot be earlier than the close of the later one. If there has been but one, traces of the glacier must have continued into comparatively recent times, or long after the period of submergence. The Trenton gravel, whether made by long continued floods which followed a first or second glacial epoch, — whether separated from all true glacial action or the result of the glacier's final melting, — is truly a post-glacial deposit, but still a phenomenon of essentially glacial times — times more nearly related to the Great Ice Age than to the present.

THE ANTIQUITY OF MAN.

Interesting as is the solution of any geological problem, it is doubly so when it involves the question of the antiquity of the human race. Archæology now joins with geology to make history. When we find that the Trenton gravel contains implements of human workmanship so placed with reference to it that it is evident that at or soon after the time of its deposition man had appeared on its borders, and when the question of the antiquity of man in America is thus before us, we are tempted to inquire still further into the age of the deposit under discussion.

It has been clearly shown by several competent archæologists that the implements that have been found are a constituent part of the gravel, and not intrusive objects. It was of peculiar interest to find that it has been only within the limits of the Trenton gravel, previously traced out by the writer, that Dr. Abbott, Prof. F. W. Putnam, Mr. Lucien Carr, and others, have discovered these implements, *in situ*. The map accompanying this chapter, on which each place is marked where implements have been found beneath the surface, illustrates this point. At the localities on the Pennsylvania Rail-

road, where extensive exposures of these gravels have been made, the deposit is undoubtedly undisturbed. No implement could have come into this gravel except at a time when the river flowed upon it and when they might have sunk through the loose and shifting material. All the evidence points to the conclusion that at the time of the Trenton gravel flood, Man in a rude state, with habits similar to those of the River-drift Hunter of Europe, and probably under a climate similar to that of more northern regions, lived upon the banks of the ancient Delaware, and lost his stone implements in the shifting sands and gravel of the bed of that stream. The term "Eskimo period" has been suggested[22] for that of the Trenton gravel, in accordance with the view that present boreal races are the descendants of the ancient palæolithic man.

The actual age of the Trenton gravel, and the consequent date to which the antiquity of man on the Delaware should be assigned, are questions which geological data alone are insufficient to solve. The only clew, and that a most unsatisfactory one, is afforded by calculations based upon the amount of erosion. This, like all geological considerations, is relative rather than absolute, yet several calculations have been made, which, based either upon the rate of erosion of river channels, or the rate of accumulation of sediment, have attempted to fix the date of the close of the glacial epoch. By assuming that the Trenton gravel was deposited immediately after the close of this epoch, an account of such calculations may be of interest. If the Trenton gravel is *post*-glacial in the widest acceptation of the term, a yet later date must be assigned to it.

When a student of surface geology, who has lived south of glacial action, examines for the first time the true glacial drift and sees the kame-like ridges and bowl-shaped depressions maintaining regular outlines and steep slopes, he cannot but be struck with the comparatively recent look of these deposits. He cannot but believe that if the great periods of time have elapsed since their deposition, which

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[22] Lewis. Proc. Acad. Nat. Sci. Philadel., 1880, p. 308.

some geologists maintain, the gravel ridges would be rounded down and the kettle-holes filled up by the erosive action of frost, rain and wind. Recent investigations in glacial geology are bringing forward many evidences that the final disappearance of the glacier in eastern America was not far remote.

Prof. Chamberlin[23] remarks that "no sensible denudation has taken place in Wisconsin since the glacial times in either drift bearing or driftless areas. Mr. Upham,[24] speaking of the lakes which dot the surface of Minnesota, says, "the lapse of time since the ice age has been insufficient for rains and streams to fill these basins with sediment or to cut outlets low enough to drain them; though in many instances we can see such changes slowly going forward."

Rev. G. F. Wright,[25] in a paper entitled "*An attempt to calculate approximately the date of the Glacial Era in Eastern North America, from the depth of sediment in one of the bowl-shaped depressions abounding in the Moraines and Kames of New England,*" finds that the accumulation of peaty matter in a typical kettle-hole in Massachusetts, whether caused by growth of vegetation or by winds and rains, is equal to a level deposit of eight feet in thickness. At the rate of one inch in a century, which is probably less than the true rate, this would place the close of the glacial epoch at less than ten thousand years ago.

A still more recent estimate has been made by Dr. Andrews,[26] who, from calculations based upon the erosive action of the great lakes, concludes that the total lake deposits made since the glacial epoch, were formed within seventy-five hundred years.

Another source of calculation is the recession of the falls of a river since glacial times. The most notable calculation of this kind is that made upon the recession of the Falls of Niagara. A gorge seven miles in length has been cut from Lewiston to the present falls. Mr.

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[23] Geology of Wisconsin, vol. ii, p. 632, 1877.

[24] Geology of Minnesota, Report for 1879, p. 72.

[25] Amer. Journal Science, vol. xxi, Feb. 1881, p. 120.

[26] Transactions Chicago Academy of Sciences, vol. ii.

Bakewell estimated the annual cutting backward of the falls to be about one yard a year, but Prof. James Hall[27] and Sir Charles Lyell[28] thought that one foot a year was a more probable amount. They showed that beds containing recent shells and mastodon teeth occurred in the banks above the gorge, at the whirlpool, three miles below the falls, and also on Goat Island above the falls, indicating that in the Champlain epoch the waters of Lake Erie extended up over the gorge and present falls, and that since that period a large portion of the gorge had been excavated. They found also at the whirlpool an ancient pre-glacial channel, which, having been filled with drift in glacial times, had forced the river to cut a new channel through the rock since that period.

There are here, therefore, data for calculating the close of the glacial epoch. If the whole gorge has been cut out since that epoch, at the rate of one foot per year, thirty-five thousand years would be required. It has been, however, more than once suggested that a portion of the gorge is pre-glacial. Prof. Dana[29] supposed about one mile of it to be pre-glacial, but Mr. Belt[30] after a personal investigation concludes that the gorge above the whirlpool was excavated nearly up to the present position of the falls in pre-glacial times. After giving the evidences upon which he founds his opinion, he says:[31] "If the conclusion at which I have arrived is correct, that the gorge from the whirlpool to the falls is pre-glacial, and that the present river has only cut through the softer beds between Queenstown and the whirlpool, and above the latter point merely cleared out the pre-glacial gorge in the harder rocks, twenty thousand years or even less is amply sufficient for the work done, and the occurrence of the glacial epoch, as so measured, will be brought within the shorter

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[27] Geology of New York, vol. iv, p. 383, et seq.

[28] Travels in North America, 1841–'2, vol. i, p. 22, et seq. See, also, Proc. Geol. Society of London, vol. ii, p. 77, vol. iii, p. 595, vol. iv, p. 19.

[29] Manual of Geology, p. 590.

[30] Quarterly Journal of Science, April, 1875, p. 135.

[31] *L. c.*, p. 154.

period that, from other considerations I have argued, has elapsed since it was at its height."

A calculation of a similar kind has been made by Prof. N. H. Winchell[32] upon the recession of the falls of St. Anthony, since the last glacial epoch. These falls, in the Mississippi river, were discovered in 1680, and a continuous record of their recession may be found since then. A narrow gorge, formed by their recession, extends from the falls to Fort Snelling, eight miles south. Below this point the valley widens, and shows indisputable evidence of having been excavated in pre-glacial times. From the falls to Fort Snelling, however, the drift, which lies above the rocky walls of the gorge, has been cut through so as to form a bluff on either side; this fact, when taken in connection with others pointing to the same conclusion, clearly shows the post-glacial age of this gorge. An ancient channel of the river, now filled with glacial drift, is described and the evidence seems decisive that, since the glacial epoch, the river, having been forced out of its old channel, has cut out a new one eight miles long, through the rock. Unlike the rocks at Niagara, those at the Falls of St. Anthony are horizontal and of unvarying composition, and any conclusions made here will be of much greater accuracy. Prof. Winchell gives three separate measurements, which result in the following terms of years required for the total recession, viz. :—12,103 years; 6,276 years; and 8,202 years. He holds that an average of these rates—8,860 years—represents the time which has elapsed since the maximum cold of the last glacial epoch.

Thus we find, that if any reliance is to be placed upon such calculations, even if we assume that the Trenton gravel is of glacial age, it is not necessary to make it more than ten thousand years old. The time necessary for the Delaware to cut through the gravel down to the rock is by no means great. When it is noted that the gravel cliff at Trenton was made by a side wearing away as at a bank, and when it

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[32] Geol. of Minnesota, Annual Rep. for 1876, p. 156 et seq. See also, Quart. Journal Geol. Society of London, Nov. 1878, p. 886.

is remembered that the erosive power of the Delaware was formerly greater than at present, it will be conceded that the presence of the cliff at Trenton will not necessarily infer its high antiquity; nor in the character of the gravel is there any evidence that the time of its deposition need have been long. It may be that as investigations are carried further, it will result not so much in proving man of very great antiquity, as in showing how much more recent than usually supposed was the final disappearance of the glacier.

In all these subjects we are but at the threshold of understanding. We are entering a field where many sciences meet and where each must help the other. No single investigation is sufficient. In the present discussion, the aim has been to define the age of the Trenton gravel, and the consequent antiquity of Man in the Delaware valley solely with reference to geological events.

At the present stage of the discussion, theories are necessarily somewhat provisional; but as facts multiply and others enter this wide field of investigation, we may hope at no distant date to arrive at more definite and trustworthy conclusions.